[redacted]

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Dear Sir:

Enclosed are three copies of the Third Project Report for the referenced contract, together with a voucher for this same project covering the period through May 28, 196[illegible].

[redacted]

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[redacted] Project ESU 5884
Third Project Report
for Period
Mid April to Mid June, 1966

During the first half of this reporting period construction was begun on the optical components required to assemble a laboratory model of the focus detection system outlined in the last progress report, and shown in Figure 1. The basic system has been assembled and tests have begun.

The feasibility of the focusing concept has been demonstrated by the operation of the present laboratory model. This model was designed to test the application of this focus detection to a rear projection system having a magnification range of 3:1 through 70:1. The present model has been tested at magnifications of 3:1, 6:1, and 70:1. In addition the model has been tested in the presence of an operating film projection light source, to confirm that suitable filters can separate the visual projection illumination from the near infrared used for focus detection.

The present focus detection image mask design was chosen on the basis of 3:1 magnification and confirms the initial theoretical analysis of mask design. The ± ¼ inch film variation from the focal plane is a small change relative to the long focal length lens required with 9" film and the 3:1 magnification. For this case the present mask will sense focus and the direction required to correct focus for a film displacement up to ± ½ inch.

However, as the magnification is increased and the lens focal length decreases, the range over which the signal can sense the direction of defocus decreases.

At the extreme range of potential magnification (70:1) the lens focal length is approximately one inch. To sense the direction of a ± ¼ inch film movement is far more difficult and requires a different mask design than the present simple grid pattern that is suitable for the low magnification ranges.

Analytical and experimental work during the next month will concentrate on creating mask configurations that will try and combine maximum sensitivity near focus, yet retain the ability to sense the direction of defocus up to ± $\frac{1}{4}$ inch when used with a short lens and high image magnification.

The present project status shows that approximately 55% of the project funds remain. This amount should be adequate to complete the projected tasks.

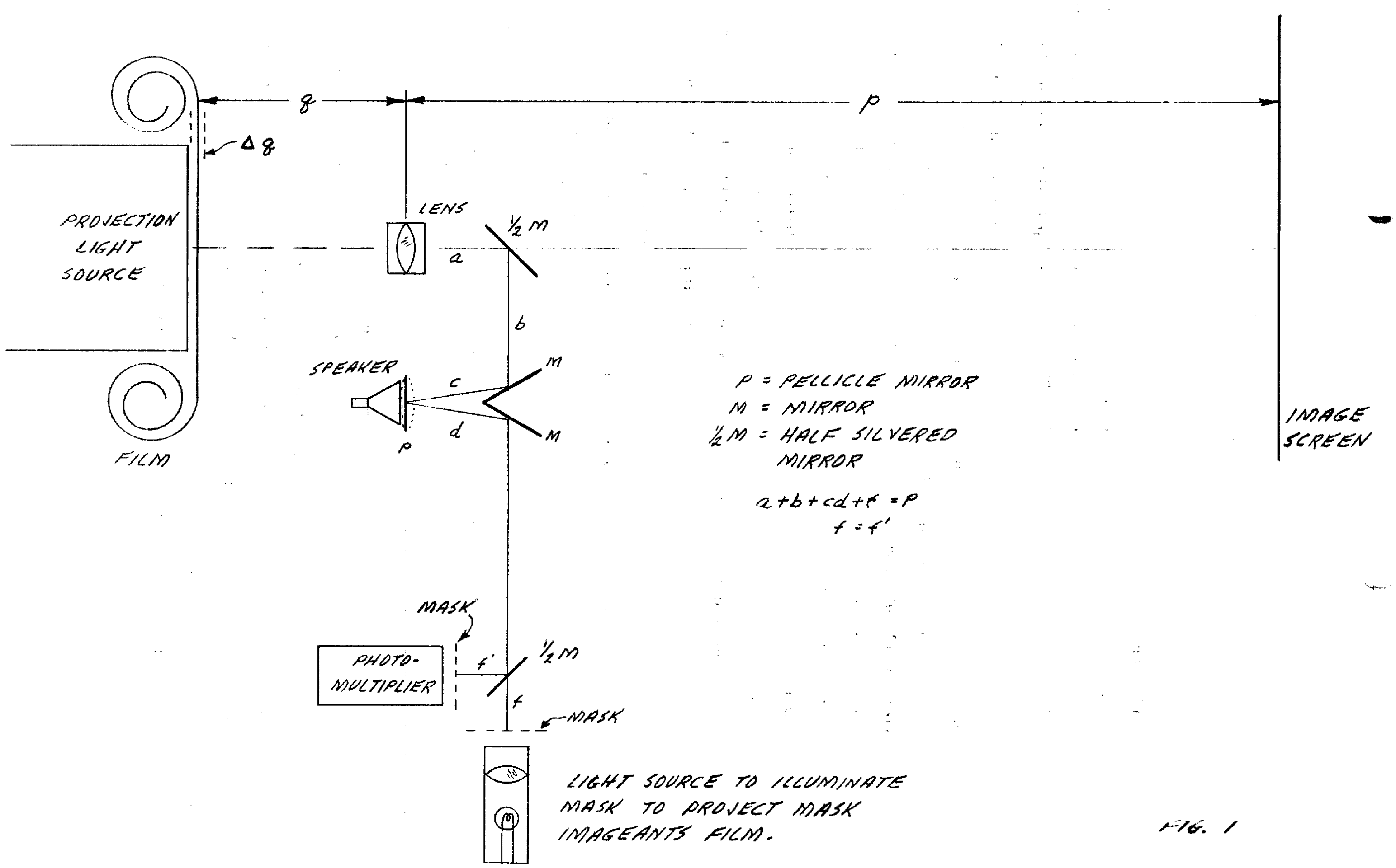
q
p
Δq
PROJECTION LIGHT SOURCE
LENS
½ M
a
b
SPEAKER
c
d
M
M
P
FILM
P = PELLICLE MIRROR
M = MIRROR
½ M = HALF SILVERED MIRROR
a+b+cd+f = P
f = f'
IMAGE SCREEN
MASK
PHOTO-MULTIPLIER
f'
½ M
f
MASK
LIGHT SOURCE TO ILLUMINATE MASK TO PROJECT MASK IMAGEANTS FILM.

FIG. 1

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Project ESU 5884
MONTHLY PROGRESS REPORT
for Month of
March 1966

During the past month the main topics presented below have been reviewed and studied in the course of selecting a tentative design for an experimental system of automatic focus detection as applied to a rear-projection film-viewing system.

A. Film Plane Detection

There are several simple mechanical and optical methods for detecting film plane position. Their application to this project, however, are not being considered, since it is not feasible to control the film plane position. A closed-loop system based on detection of film plane position would require capability of repositioning the film plane to a desired location. Since this is not permitted, a film-plane detection system would be an open-loop system to focus the optical system on the basis of the measured displacement of the film. Such an open-loop system would not provide the accuracy and reliability required.

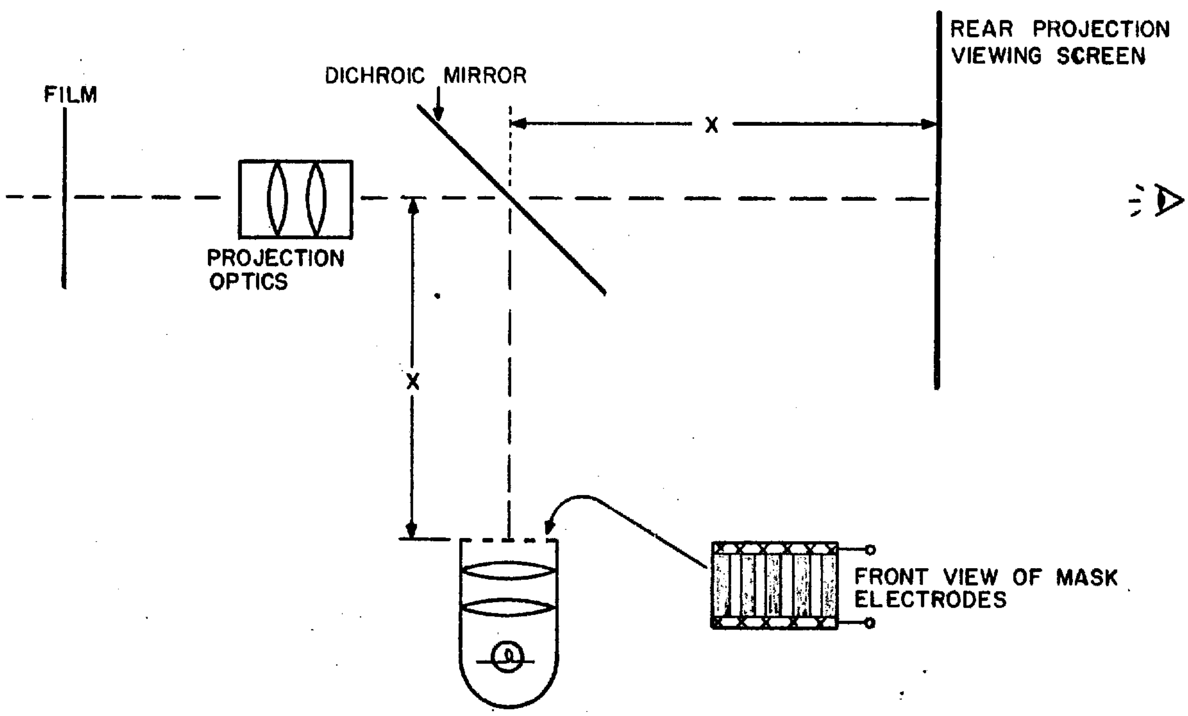
B. Image Plane Detection

Since the object of the focusing system is to achieve a sharp image on the ground glass of a rear-screen projection system, it is desirable that the sensing element detect the sharp image at the image plane. The detector output can then be used to control the focus of the optical system in a closed-loop system. The source of the image used to detect sharp focus can be one of the following three:

Primary Image Recorded on the Film--The use of primary images and a nonlinear photocell to detect their sharpness is the basis of the mobility aid for the blind developed in this Laboratory. The main limitation of this technique as applied to the present problem is that the film to be reviewed or scanned may contain photographs of water or fairly uniform cloud areas, with little sharp detail in the film image. The focus system would become inoperative when such sections of film passed the viewer and small significant pinpoint areas might go unnoticed because of a defocused position.

Grain in the Film Image--The tight, sharp grain pattern that exists in the typical aerial film makes an ideal pattern for detection by nonlinear photocell techniques. However it would require a magnification of 100 to 200 diameters. If the rear screen projection system operated at a constant magnification ratio or with a very limited range, additional magnification could enlarge the film grain pattern on the nonlinear photocell enough to make this approach attractive. However, with the wide range of magnifications that are desirable, use of the film grain as the basic focusing image becomes more difficult. While a secondary optical system whose magnification varies inversely with the main optical system could be used to present a relatively constant grain size on the detector photocell, such a subsystem would be in series with the focus detection element; any errors or shifts in its focus with magnification change could contribute errors in the overall focus-detection system. While these could be minimized by careful optical design, this system would be more difficult to implement than the following system.

Projection of a Special Image for Focus Detection--The following sketch indicates the basic principle of how such an image would be projected onto



Sketch 1

the film. A dichroic mirror that passes visual light but reflects infrared is inserted at a 45-degree angle just beyond the last element of the lens system. An illuminated mask consisting of a series of vertical slits and bars is at a right angle to the optical axis. The pattern is at an identical distance from the center of the mirror as the viewing screen*; therefore the lens system images the illuminated slit pattern onto the film in exact focus when the optical system is adjusted to project the film image in exact focus on the screen. The dichroic mirror passes visible light and reflects infrared. Approximately 2 to 5 percent of the infrared pattern projected onto the film is reflected by the film and the dichroic mirror and is refocused back at the plane of the illuminated mask. Because of the dichroic mirror, the image of the mask will be in the infrared spectrum and thus not be visible by the viewer. If the film plane shifts so as to throw its projected image out of focus on the screen, the image of the slitted mask will be out of focus at both the film plane and at the reflected image at the plane of the mask. Because of the defocusing, infrared light will illuminate the front surface of the mask pattern.

As described later, suitable additions to the system permit this light to be detected and used to control the focus of the projection lens system to maintain a sharp return image of the mask at the mask plane. This automatically ensures that the image of the film plane on the viewing screen is also in sharp focus. This system is now independent of the magnification of the lens system, since the image used for focusing passes through the lens system once in each direction. The return image is always the same size at the point where detection is accomplished.

C. Methods of Detecting Sharp Focus of the Reflected Mask Image

When the reflected image of the mask is in exact sharp focus, all light coming through the slits returns back through the slits and no illumination falls on the front surface of the opaque portions. Three methods have been considered for detecting the defocus illumination on the front surface of the mask.

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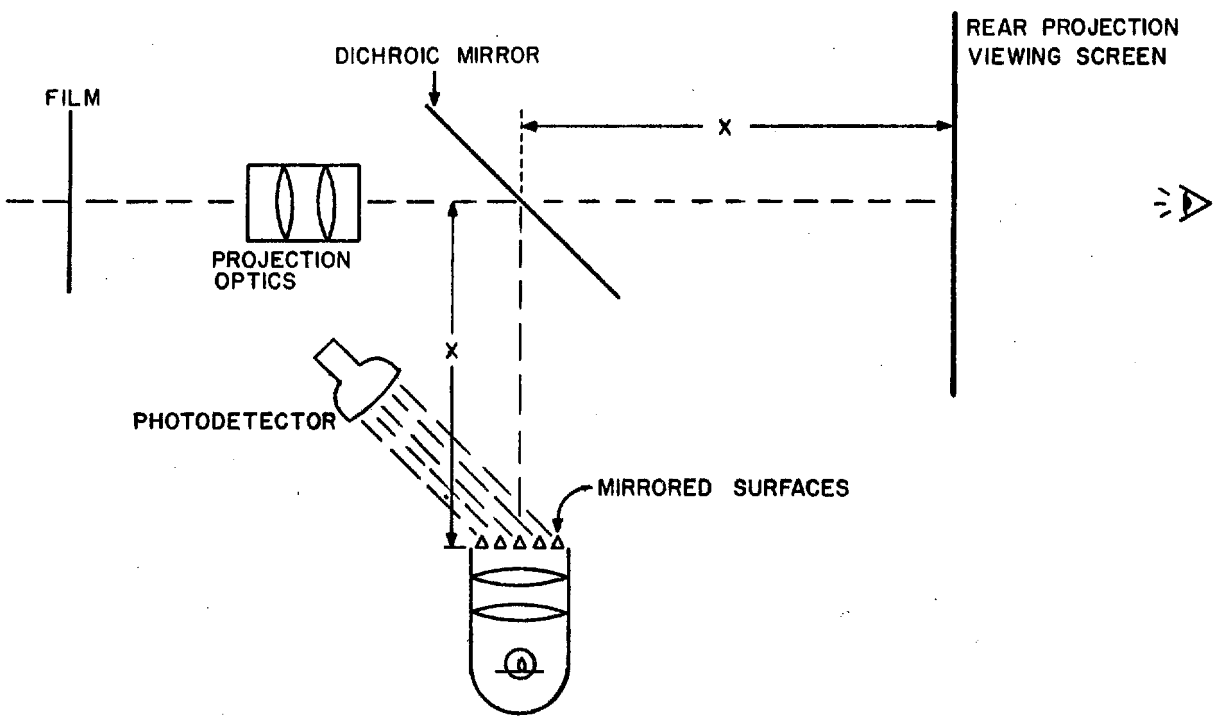
*A slight correction may be required for differences in IR and visual focal planes of the projection optics. IR as used in this system will be within 7000 to 9000 angstroms.

(1) It is possible to coat the front surface of the mask with photoconducting material and place electrodes at the top and bottom ends of the vertical bars. If the image is slightly defocused and illumination spreads onto the vertical elements, a change in conductivity between the two electrodes can be detected. This method is the simplest to implement optically but is complicated by the requirement of specialized photocell fabrication. The photocell construction and chosen mask pattern are integrated and experimentation with various mask patterns is severely restricted by the requirement that each mask have a photoconductive front surface. Optimum sensitivity and electrode placement may or may not be compatible with an ideal mask pattern.

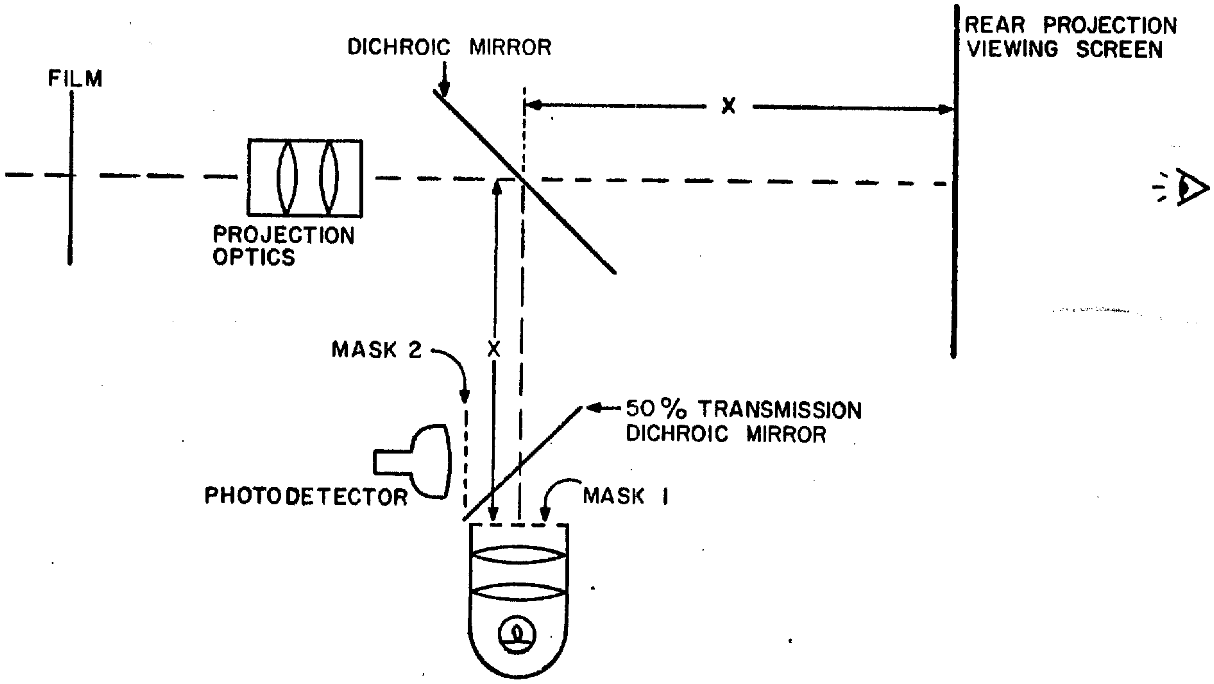
(2) Small angled mirror surfaces can be mounted in front of each line in the mask, as shown in the following sketch. Any light due to



Sketch 2

a defocused return image that would fall on the front surface of the mask is then reflected out of the optical path and can be sensed. This approach separates the mask from the photodetector. It does however require that the mask design be capable of incorporating the reflective mirror surfaces.

(3) A third method, offering the most flexibility but at a penalty of the loss of some illumination in the returned image, is shown in the following sketch. A half-silvered mirror at a 45-degree angle is placed in front of Mask 1 to reflect a portion of the reflected



Sketch 3

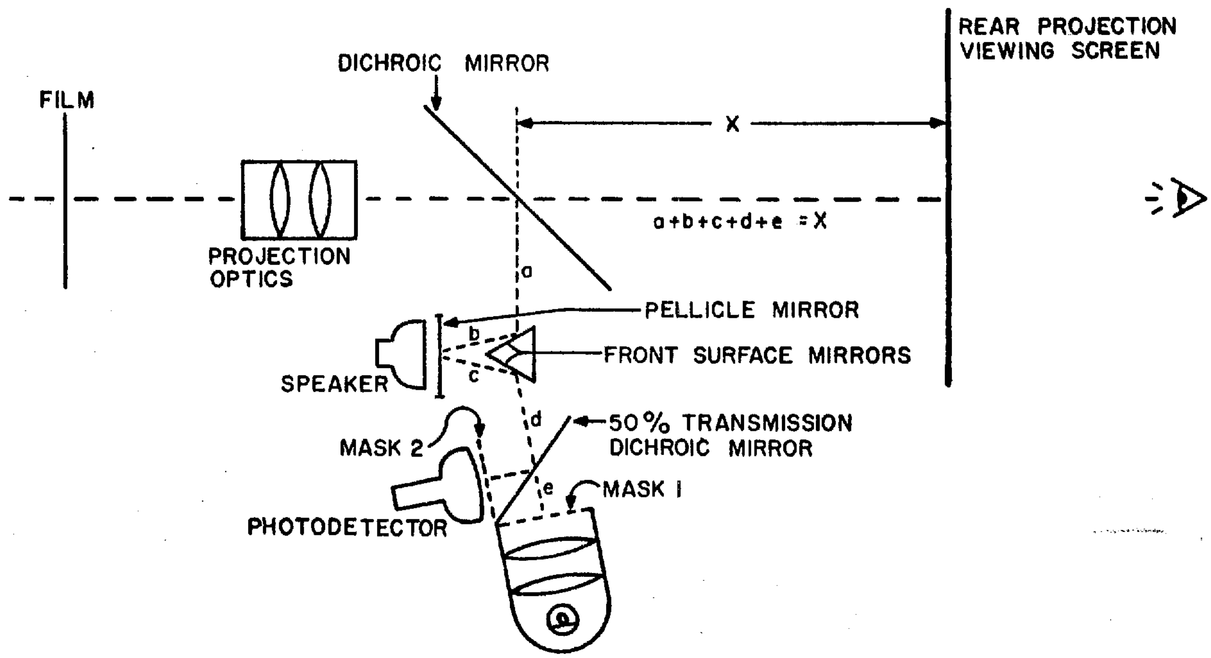
mask image from the film at 90 degrees to the location of Mask 2. Mask 2 is identical to the vertical-bar Mask 1, which generates the image but is displaced one bar width. Thus a sharp image returning toward Mask 1 is directed to Mask 2 (displaced one bar width) which intercepts all the in-focus image. When defocus occurs, illumination passes through the slits to a photodetector located behind Mask 2. Any photodetector can be used and the masks can be simple machined pieces of thin metal in the desired patterns. The introduction of the second halftransmission dichroic mirror results in a 4-to-1 loss in light returning to the photodetector compared to the other two methods. However, experience with a system operating on a similar basic principle developed for eye-accommodation studies indicates that more than sufficient illumination is returned from the film and that this loss of light will present no problem. Therefore, this method will be implemented in the experimental model because of its simplicity and independence of mask and photodetector.

D. Method for Determining the Direction of the Focus Correction

The point of exact focus can be determined when the minimum-illumination signal is detected by the photodetector. However, without introducing a slight perturbation in the optical system, the static photocell output does not indicate whether a minimum exists and, if not a minimum, which direction the focus must be corrected to approach minimum. This sensing was accomplished in our mobility-aid work using the nonlinear photocell by vibrating the photocell axially at a frequency of several hundred cycles per second and over a distance of 0.010 to 0.015 inch. As previously described (in references accompanying the proposal), the output signal from the photocell for out-of-focus images is a sine wave of the same frequency as the photocell vibration. The phase of this sine wave reverses by 180 degrees depending on which side of the image plane the photocell is located. Because of the symmetry of small perturbations about a sharp image plane when the photocell vibration is exactly centered on the image plane, the output signal is the second harmonic of the basic photocell vibration frequency. A similar technique is required in the present application. This could be accomplished by small vibrations of either Mask 1 or Mask 2. While this is a possible technique, it requires planar mechanical vibration of the mask. A simpler (and more elegant) method is the introduction into the optical path of a small, variable-focal-length optical component. A simple method has been devised to accomplish this by using a thin-film pellicle mirror, vibrated by air coupling from a small radio speaker. Laboratory experiments have shown this to be an ideal way to achieve small variations in the optical path length. The vibrating mirror adds some optical complexity, but eliminates the need for vibratory systems moving significant masses--such as the masks--in a linear fashion.

E. Schematic Sketch of Experimental Focus System

The following sketch shows schematically the proposed breadboard system for preliminary tests of this focus-detection system. With the pellicle mirror in the flat position the other optical path lengths are so adjusted that the returned image of the mask is in exact focus when the film plane image is in exact focus on the viewing screen. (These dimensions are all rigidly built into the system.) A small perturbation, introduced by the vibrating pellicle mirror, is used to sense any defocus of the return mask image due to shifts in the film plane position. This signal is used to correct the



Sketch 4

focus of the main projection optics to compensate for the film plane change. When the reflected mask image is returned to sharp focus, the film image on the viewing screen also returns to sharp focus.

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April 18, 1966

 FILE 99742-6

FIRST MONTHLY PROGRESS REPORT -- [redacted] PROJECT 5884 STAT

The research effort outlined in [redacted] Proposal ES 65-88 has been reviewed with the client project monitor for the purpose of agreeing on a specific experimental effort of maximum value to the client and incorporating [redacted] latest ideas on automatic focusing techniques. STAT STAT

The Work Statement outlined in Proposal ES 65-88 was as follows:

(1) Approximately one man-month to study specific requirements and for planning a specific set of experiments.

(2) Four man-months to perform laboratory experiments, including:

 (a) selection of photocell that will best meet the requirements of resolution, speed of response, and light sensitivity,

 (b) determination of the best method (e.g., beam-splitting) to incorporate the focus detection unit with the optical paths of the various equipments under consideration, and

 (c) determination of means to accommodate the focus detection with the wide range of image magnification used in some of the equipments.

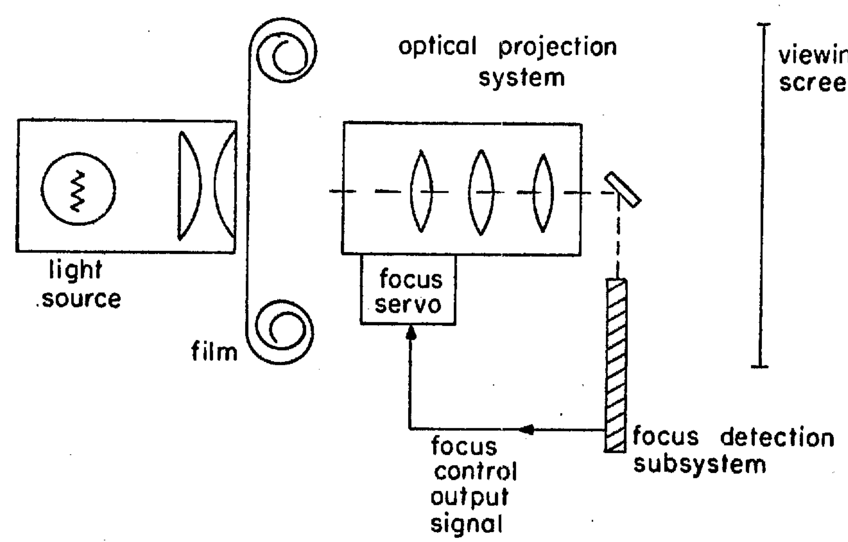
(3) One man-month to evaluate the results and make specific recommendations.

The laboratory effort outlined in Item (2) was discussed in detail with the client and the following plan was selected.

The application of automatic focus detection to a rear projection film viewer will be taken as the specific application for detailed attention during this project. In this equipment, a defocusing problem exists because of the undesirability of rigidly controlling the film plane position during either the scanning mode or stationary viewing. The variation in film-plane position results in a defocused image on the viewing screen, which cannot be compensated for by the focusing accommodation of the viewer's own eyes.

(This is in contrast to such other direct viewing systems as the stereo-microscope, in which the viewer's eyes are part of the basic focusing system. For these systems automatic focusing techniques would have to view the final image on the retina of the viewer's eye to provide truly automatic focusing. The development of such techniques are under way on parallel projects in this laboratory but their applications are not within the scope of the present project.)

A basic focus detection system to be breadboarded will take into account the film sizes and image magnification values that may be typical of future rear projection film viewers. The basic focus detection unit would be designed to fit into a rear projection system, as shown functionally in the following diagram.



The placement of the focus detection unit beyond the last element of the film viewer optical system will permit it to detect the focus of the image appearing on the ground glass. The focus unit will be capable of detecting not only exact focus but the direction in which the optical elements must be moved in order to correct an out-of-focus condition. Studies will be made of two basic types of focus detection units. One unit, using nonlinear photocell techniques, will operate from the images actually appearing on the film to determine if sharp focus exists. The second basic type of focus unit will generate a sharp optical image in the infrared portion of the spectrum and project this image onto the film plane for use in determining focus. This will permit sharp focus to be maintained when the film image does not contain sufficient sharp contrast edges to allow the nonlinear photocell to detect focus. For example large uniform cloud areas would be difficult to use to determine sharp focus.

The possibility of using the basic grain pattern in the film with a nonlinear photo cell will be investigated since this would also make the focus detection independent of the images recorded on the film.

The output signal from the focus detection unit will provide the control signal to drive the focus control mechanism. The design of this mechanism is not part of this research contract but consideration will be given to its function, since detection and control of the focus are closely related.

For the specific application of rear projection viewers, the control system would not move the film plane position during scan because of the danger of scratching the film. The most likely focusing control would be a mechanical servo system to position selected optical elements in the projection system to maintain a sharply focused image on the viewing screen despite small motions of the film plane.

If time and funds permit, preliminary consideration will be given to the possibility of incorporating a variable-focus membrane mirror in the optical system to control focus. Many problems are known to exist with such an approach; yet, the mechanical simplicity and high speed of response (1 to 10 ms) would justify a preliminary examination of such a possibility. This is particularly true, since an implementation of the focus detection system might use the same mirror for focus detection. However, the incorporation of such a membrane mirror in the focus detection system does not require that it be placed in the primary image optics, should its use there be undesirable.

Next 1 Page(s) In Document Exempt

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